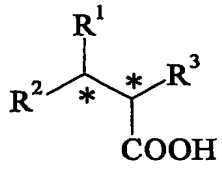
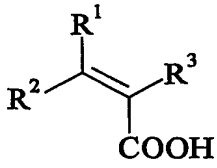
claim

1. A method for producing an optically active carboxylic acid represented by the formula [2]:



[2]

wherein R^1, R^2 and R^3 independently represent a hydrogen atom, an alkyl group, an alkenyl group or an aryl group, the groups may have a substituent, R^1, R^2 and R^3 is not a hydrogen atom simultaneously, R^3 is a group other than a hydrogen atom when one of R^1 and R^2 is a hydrogen atom, R^3 is a group other than a hydrogen atom and a methyl group when both of R^1 and R^2 are hydrogen atoms, and R^1 and R^2 are different groups other than a hydrogen atom when R^3 is a hydrogen atom, and at least one of the two carbon atoms marked with * represents an asymmetric carbon atom, comprising the step of subjecting an α,β-unsaturated carboxylic acid represented by the formula [1]:

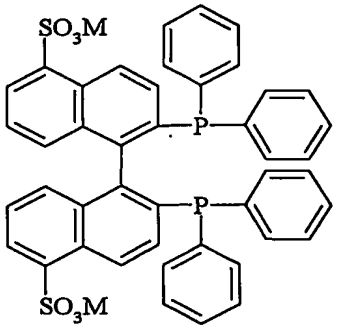


[1]

wherein R^1 to R^3 have the same meanings as those in the formula [2], in the presence of a sulfonated BINAP-Ru complex represented by the formula [3]:

$$[RuX(arene)\{(SO_3M)_2\text{-BINAP}\}]X \quad [3]$$

wherein $(SO_3M)_2$-BINAP represents a tertiary phosphine represented by the formula [4]:



[4]

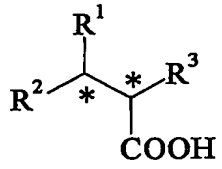
M represents an alkaline metal atom, X represents a chlorine atom, a bromine atom or an iodine atom, and arene represents a benzene or an alkyl-substituted benzene, in an aqueous solvent, to an asymmetric hydrogenation.

2. The method according to claim 1, wherein the aqueous solvent is water or a mixed solvent of water and a water-insoluble organic solvent.

3. The method according to claim 1, wherein the sulfonated BINAP-Ru complex is recovered.

4. The method according to claim 1, wherein the sulfonated BINAP-Ru complex is recycled.

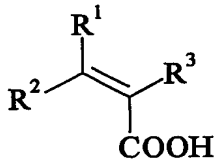
5. A method for producing an optically active carboxylic acid represented by the formula [2]:



[2]

wherein R^1, R^2 and R^3 independently represent a hydrogen atom,

an alkyl group, an alkenyl group or an aryl group, the groups may have a substituent, R^1, R^2 and R^3 is not a hydrogen atom simultaneously, R^3 is a group other than a hydrogen atom when one of R^1 and R^2 is a hydrogen atom, R^3 is a group other than a hydrogen atom and a methyl group when both of R^1 and R^2 are hydrogen atoms, and R^1 and R^2 are different groups other than a hydrogen atom when R^3 is a hydrogen atom, and at least one of the two carbon atoms marked with * represents an asymmetric carbon atom, comprising the step of subjecting an α,β-unsaturated carboxylic acid represented by the formula [1]:



[1]

wherein R^1 to R^3 have the same meanings as those described above, in the presence of a recovered sulfonated BINAP-Ru complex used in the method according to claim1 in water or a mixed solvent of water and a water-insoluble organic solvent to an asymmetric hydrogenation.

6. The method according to claim 5, wherein the α,β-unsaturated carboxylic acid is hydrogenated in the presence of an aqueous solution containing the sulfonated BINAP-Ru complex, and the aqueous solution is obtained by separating a water phase from the reaction mixture after the asymmetric hydrogenation in the method according to claim 1.